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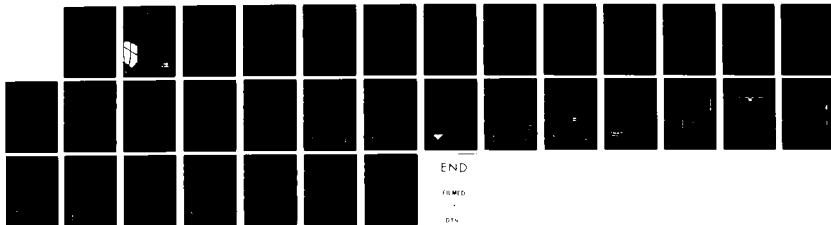
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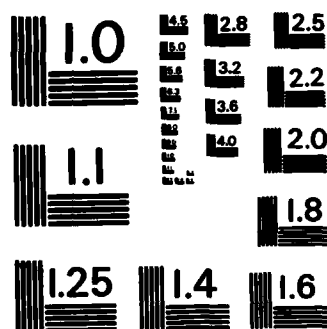
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TECHNICAL REPORT P-129  
September 1982

FACILITY FLEXIBILITY AND THE STANDARDIZATION  
OF BUILDING DESIGN MODULES

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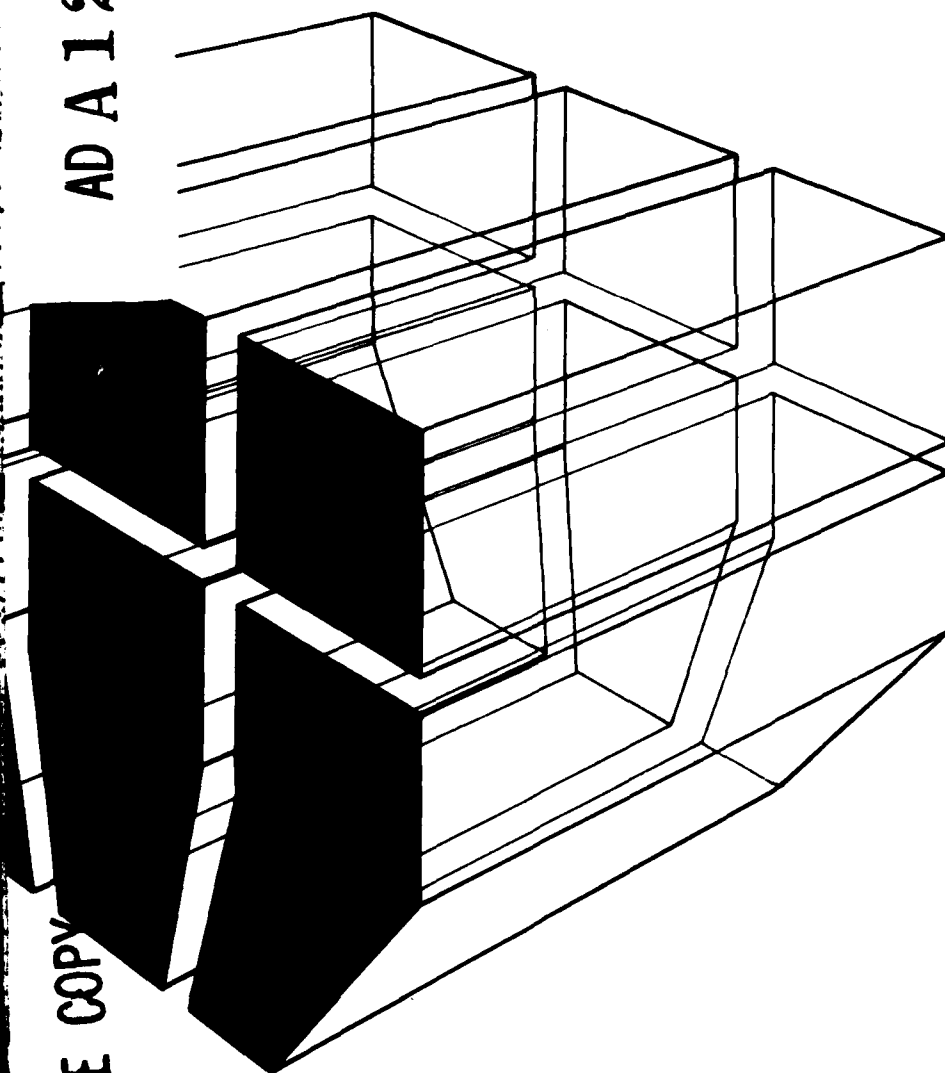
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) <p>→ The U.S. Army Corps of Engineers is developing a modular approach to new building designs. This report documents a procedure that allows the needs of users to be considered during the development of standardized modules.</p> <p>To accomplish this objective, the U.S. Army Construction Engineering Research Laboratory:</p> <p style="text-align: right;">_____ ) m</p>		



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1. Reviewed Army facility design standardization procedures, policies, and documents contained in Army Regulations, Engineer Regulations, Engineer Technical Letters, and other applicable Department of Defense (DOD) regulations;
2. Examined the relationships between standardization and a facility's flexibility, life-cycle costs, and functional life;
3. Developed a method to generate a standardized design module compatible with the Office of the Chief of Engineers' current standardization program; *Inc*
4. Investigated the application of the standardization procedure using modules to achieve facility flexibility for several facility types within the Corps of Engineers.

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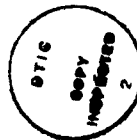
## FOREWORD

This investigation was performed for the Directorate of Military Programs, Office of the Chief of Engineers (OCE), under Project 4A762731AT41, "Design, Construction, and Operation and Maintenance Technology for Military Facilities"; Task A, "Architectural Research and Development in Support of Military Facilities"; Work Unit 047, "Criteria for Balancing Flexibility and Standardization in Building Design." The applicable QCR is 3.10.001. The OCE Technical Monitor was Richard Cramer, DAEN-MPE-B.

This investigation was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (CERL). Mr. Edward Lotz is Chief of FS.

Mr. Rambir Singh of the architectural firm of Morton, Alvarez, Wolfburg, and Terracido of Miami, FL, contributed information about the U.S. Army Corps of Engineers' current Buildings Standardization and Design System (BSDS) program.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.



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# FACILITY FLEXIBILITY AND THE STANDARDIZATION OF BUILDING DESIGN MODULES

## 1 INTRODUCTION

### Background

The Army, through the Corps of Engineers' Military Construction program, has always emphasized the development of standard designs that installations in different regions of the country can use. The purpose of standardizing military facilities, of course, is to reduce building design costs. Moreover, if the design is a valid solution for many locations, more users will be satisfied with their facilities.

Standardization of complete designs, however, can cause a number of problems. For example, adapting a site so that a standard design can be built may be more complicated than developing a new design made up of standard modules. Therefore, standardized designs must be flexible enough to meet the demands of various users and site conditions. The U.S. Army Construction Engineering Research Laboratory (CERL) has examined ways to produce such designs. (CERL Technical Report P-128 documents research on the characteristics of mission-responsive facilities).<sup>1</sup>

### Objective

The purpose of this report is to explain a modular approach to developing components for facility designs, and to document a procedure that allows the users' needs to be considered during the development of standardized modules.

### Approach

To accomplish this objective, CERL:

1. Reviewed Army facility design standardization procedures, policies, and documents contained in Army Regulations (ARs), Engineer Regulations (ERs), Engineer Technical Letters (ETLs), and other applicable Department of Defense (DOD) regulations (Chapter 2).

<sup>1</sup>Robert Porter, Jon Rodgers, and Charles Lozar, *Developing Information for Mission-Responsive Maintenance Facilities*, Technical Report P-128 (U.S. Army Construction Engineering Research Laboratory [CERL], September 1982).

2. Examined the relationships between standardization and a facility's flexibility, life-cycle costs, and functional life (Chapter 3).

3. Developed a method to generate a standardized design module compatible with the Office of the Chief of Engineers' (OCE) current standardization program (Chapter 4).

4. Investigated the application of the standardization procedure using modules to achieve facility flexibility for several facility types designed within the Corps of Engineers (Chapter 5).

### Definitions

"Standardization" and "flexibility" have specific meanings when referring to building construction. Traditionally, standard designs have not been considered flexible or versatile enough to be long-term architectural design solutions. Often, flexible designs have meant "custom" designs for particular projects, and have increased the costs of the Corps of Engineers' nationwide construction program.

In this report, "standardization" means the use of standard modules for the design of repetitive-type building facilities. "Flexibility" refers to a building standard module's usefulness for a wide range of activities, and its adaptability throughout the functional life of the facility.

### Mode of Technology Transfer

The information in this report will impact on the Corps of Engineers' Design Information System (DIS)-Building Standardization Design System (BSDS), and will be used by OCE to contract with architect-engineer firms for the development of mission-responsive standardized modules for various facility types.

## 2 U.S. ARMY CORPS OF ENGINEERS' POLICY ON STANDARDIZATION

This chapter discusses Corps of Engineers procedures for developing standardized designs, and summarizes documents governing standardization.

### Design Procedures

The U.S. Army Corps of Engineers has several options when selecting a building design delivery system—depending on the type of building and its particular requirements:



1. Use established designs—to benefit from standard or nonstandard designs that have been completed.

2. Use industrialized building system designs—to benefit from the advantages of industrialized building systems.

3. Use ongoing designs—to benefit from any completed portion of the current design effort.

4. Develop new standards—to benefit from Army-wide standardization of a facility design.

5. Develop individual custom designs—to satisfy one-of-a-kind design requirements.

6. Develop multi-facility custom designs—to benefit from a single contract providing design solutions for common elements of several similar facilities.

In the past, the Army has used these design procurement methods with mixed success. Standard building designs are now receiving more attention—primarily because of Congress' interest in reducing design costs and speeding the facility development process.

In its report on the Military Construction Appropriations Bill of 1980, the Committee on Appropriations submitted the following statement:

The military services advise the Committee that they seek to make use of standard designs wherever possible. Yet very few of the projects submitted for construction funding are based on standard designs. The Department is strongly encouraged to require greater use of standard designs that can be site adapted that will result in reduced design costs. As a rule, according to testimony, site adaptations can be accomplished for 2 or 3 percent of the facility cost, or about half of the cost of a complete new design. A portion of the reduction recommended in the design funds was based on the increased use of standard designs.<sup>2</sup>

From the committee's report, then, it is clear that greater use of standard design in military construction is warranted.

For facilities likely to be built in many locations,

<sup>2</sup>Committee on Appropriations, "Report on the Military Construction Appropriations Bill of 1980."

standard design drawings and design analyses are prepared. This information is detailed enough to be used for project drawings after necessary field modifications covering site adaptations and deletion of inapplicable material. Standard design drawings can be adapted to widely separated geographical areas and are usually designed for seismic conditions, three roof-loading conditions, three heating zones, and three fuels. Alternate wall sections, details, and building elevations are included as required to illustrate these variations. These drawings are modified only under certain conditions (ER 1110-345-710).<sup>3</sup>

There are five kinds of standard drawings:

1. Standard drawing: a set of working drawings suitable (with the addition of foundations) for constructing a building (see p 12 of ER 1110-345-710).

2. Definitive drawing: about 25 percent of the normal architect-engineer design work will be done since floor plans and critical items will be fixed (ER 1110-345-710).

3. Sketch drawing: less detailed than the definitive drawing; primarily fixes scope and general functional layout.

4. Design guide: a book that covers a specific family of facilities. Contains data on design, functional requirements, and programming, supplemented with sketches.

5. Field office standard designs: specific repetitive designs for local or required purposes (see ER 1110-345-711).<sup>4</sup>

There is an established procedure for obtaining a standard design:

1. Facility scope defined.

2. Facility criteria and drawing format reviewed and clarified.

3. Design stages, types of reviews and approvals established.

<sup>3</sup>*Drawings*, Engineer Regulation (ER) 1110-345-710 (Department of the Army [DA], Office of the Chief of Engineers [OCE], 17 April 1981).

<sup>4</sup>*Standard Designs by Field Offices*, ER 1110-345-711 (DA, OCE, 30 April 1974).



4. All basic criteria clarified with OCE.
5. Design executed in steps and stages.
6. Design reviewed.
7. Approval of concept drawings, preliminary design, and specification outlines.
8. Design completed in accordance with ER 1110-345-100.<sup>5</sup>
9. Final design approved at OCE and major command (MACOM) proponent.
10. Originals sent to OCE (DAEN-MCE-A) after approval.
11. Reproduction and distribution with reference copies at OCE kept as defined by ER 1110-345-720.<sup>6</sup>
12. Originals retained and updated for 1 year.
13. Design reference becomes part of index of designs for military construction, as defined in EP 1110-345-2.<sup>7</sup>

The current set of information for developing standard designs includes:

1. Facility description and mission/purpose.
2. Cost/space limitations or guidance.
3. Functional requirements.
4. Technical design criteria.
5. List of design zones and design criteria.
6. List of Corps of Engineers design documents.
  - a. Drawings (ER 1110-345-710)
  - b. Specifications (ER 1110-345-720)

<sup>5</sup>*Design Policy for Military Construction*, ER 1110-345-100 (DA, OCE, 19 June 1970).

<sup>6</sup>*Specifications*, ER 1110-345-720 (DA, OCE, 17 January 1977).

<sup>7</sup>*Index of Designs for Military Construction*, Engineer Pamphlet (EP) 1110-345-2 (DA, OCE, 18 January 1980).

#### c. Design Analysis (ER 1110-345-700).<sup>8</sup>

An index of standard designs can be found in EP 1110-345-2, which contains a list of drawings for current and temporary facilities grouped into the following series and building types:

- 100: Operational and training facilities
- 200: Maintenance and production facilities
- 400: Supply facilities
- 500: Hospital and medical facilities
- 600: Administrative facilities
- 700: Housing and community
- 800: Utilities and ground improvements.

When designs become obsolete, they are deleted from the index and placed in an inactive archival file. New designs or changes to listed designs appear in a revision issued annually (see EP 1110-345-2).

OCE has responsibility for standard designs of repetitive facilities, as defined in AR 415-20;<sup>9</sup> although the actual design preparation may be assigned to field offices, in accordance with ER 1110-345-711. The division or district engineer preparing contract documents from standard designs must specify site adaptations and modifications for unusual foundation conditions and outside utilities such as exterior grading, drainage, erosion control, planting, roads, walks, and parking areas. The division or district engineer also must incorporate current criteria issued by OCE in guide specifications and other documents.

Division and district engineers preparing contract documents from locally developed designs or from approved definitive drawings have complete design responsibility, subject to the conditions in AR 415-20, ER 1110-345-710, and ER 1110-345-720, or as otherwise stated in the design directive. According to the "Responsibility of the Architect-Engineer" clause in Defense Acquisition Regulation (DAR) 7-607.2,

<sup>8</sup>*Design Analysis*, ER 1110-345-700 (DA, OCE, 15 October 1976).

<sup>9</sup>*Construction Project Development and Design Approval*, AR 415-20 (HQ, DA, March 1974).



architect-engineers are fully accountable for design. In addition, architect-engineers are responsible for ensuring that a design can be built within budget, in accordance with DAR 7-668.3.

For Army construction, division and district engineers are authorized to modify drawings for standard designs to meet local siting, foundation, topographic, or climatic conditions; to avoid unnecessary construction features or costs; and to correct errors. Other modifications not authorized by OCE require approval of the division engineer and are subject to the controls required by ER 1110-345-100, paragraph 3. When the modifications involve any of the following, however, the modified drawings, with appropriate explanations, are to be submitted to OCE for approval before advertising:

1. Deviations from space criteria or limitations.
2. Changes in loading or design of structural members, or changes in materials or conventional construction methods that could affect structural stability.
3. Deviations that cause a significant increase in funding requirements.

Changes issued through OCE Engineer Technical Letters, revised manuals, and revised guide specifications are authorized and are implemented according to ER 1110-345-100 (see ER 1110-345-710).

OCE provides funds to cover the direct and immediate-supervision costs for field preparation and maintenance of standard designs. These funds are used only for the standard-design operations, and not for site adaptation of the standard design for a specific project (see ER 1110-345-711).

#### **Military Construction—Army (MCA) Documents Governing Standardization**

1. EP 1110-345-2—*Index of Designs for Military Construction* (15 Nov 1976). This regulation lists the available standard designs for military construction. These designs are grouped under the following categories: Operational and Training Facilities, Maintenance and Production Facilities, Supply Facilities, Hospital and Medical Facilities, Administrative Facilities, Housing and Community, Utilities and Ground Improvements. A brief facility description, the number of sheets, the date of design, and the gross square footage are given for each listing.

2. ER 1110-345-720—*Engineering and Design—Specifications* (17 Jan 1977). Related documents: ER 1110-345-100, Engineering Form 3078. This regulation gives the procedures to be followed in preparing, processing, obtaining approvals, and disposing of specifications prepared for military construction. The regulation is applicable to all OCE elements and all field operating agencies having military construction responsibilities.

The issues covered in ER 1110-345-720 are outlined below.

Issue Applicable To:			
	Master Planning	Standard Design Develop- ment	Implemen- tation
Outline specifications		•	
Project specifications			•
Guide specifications			•
Standard technology specifications		•	
Reference publications	•	•	
Preparation of specifications by A-E		•	•
Review and approval			
Intent of guide and standard specifications			

3. ER 1110-345-710—*Engineering and Design—Drawings* (18 Apr 1969). Related document: ER 1110-345-720. This regulation gives procedures for preparing, approving, and transmitting drawings for military construction. The scope includes drawings, other than shop drawings, prepared at all stages of design and construction for Army and Air Force projects.

The issues covered in ER 1110-345-710 are outlined below.

Issue Applicable To:			
	Master Planning	Standard Design Develop- ment	Implemen- tation
Description of standard design drawings	•		
Field modifications		•	
Authorization for deviations		•	
Deficiency reports			•



4. ER 1110-345-700—*Engineering and Design—Design Analysis* (15 Jul 1975). Related documents: AR 415-10,<sup>10</sup> AR 415-20, ER 1110-345-100, ER 1110-345-710. This regulation establishes the requirements and procedures for preparing design analyses for military construction projects. A design analysis summarizes all functional and engineering criteria, design information, and calculations applicable to project designs, plans, and specifications. The design analysis is used for:

- Review, approval, and record-keeping
- Adaptation of designs to other sites
- Re-evaluation and modification of construction.

Unless specifically exempted, all new construction projects and projects involving modernization of existing facilities must have design analyses.

The issues covered in ER 1110-345-700 are outlined below.

	Issue Applicable To:		
	Master Planning	Standard Design Development	Implementation
Content	•		
Preparation	•		
Detailed requirements for building	•		
Requirements for other facilities	•		
Submission	•	•	
Disposition	•	•	
Recommendations for improvement			•

5. ER 1110-345-711—*Engineering and Design—Standard Designs by Field Offices* (30 Apr 1974). Related documents: ER 1110-345-700, ER 1110-345-710, ER 1110-345-720, TM 5-800-2.<sup>11</sup> This regulation establishes assignments and procedures for field offices preparing OCE standard drawings, specifications, and design analyses (including cost estimates where applicable).

<sup>10</sup> *General Provisions for Military Construction*, AR 415-10 (HQ, DA, 2 February 1972).

<sup>11</sup> *General Criteria: Preparation of Cost Estimates; Military Construction*, TM 5-800-2 (DA, March 2, 1959).

Standard drawings, specifications, and design analyses are prepared and used under the supervision of OCE for repetitive construction. Division engineers prepare standard designs in accordance with the procedures in this ER. Duties delegated to division engineers may be assigned to district engineers as necessary. The office that prepares a standard design usually updates it.

This regulation applies to all OCE elements and all field operating agencies having military construction design responsibility.

Standard designs in the field are prepared according to ERs 1110-345-100, -700, -710, -720, and TM 5-800-2. Funds to cover the direct and immediate supervision costs in connection with field preparation and maintenance of standard designs are provided through OCE. These funds cannot be used for adapting a standard design to a specific site.

6. ER 1110-345-100—*Engineering and Design—Design Policy for Military Construction* (14 Dec 1973). Related document: AR 415-20. This regulation establishes the policy and procedures for design of military facilities.

The Chief of Engineers is responsible for developing and distributing standard plans or uniform criteria and specifications for facilities that are as economical as possible. The district engineer obtains functional requirements and appropriate approvals from using services.

The issues covered in ER 1110-345-100 are outlined below.

	Issue Applicable To:		
	Master Planning	Standard Design Development	Implementation
Use of standard designs	•		
Design responsibility	•		
Current Design Information System (CDI)	•		•
Correction of standard designs			•

To achieve uniformity and economy in the design and construction of military facilities, OCE has started



emphasizing the use of computer technology for designing and drafting military construction projects. The initial systems—to be developed for Table of Organization and Equipment (TOE) maintenance facilities—are: (a) a Design Information System (DIS) consisting of stored standard designs, plans for previously constructed buildings, and definitive designs which make it easier to adapt construction to specific sites; and (b) a Building Standardization Design System (BSDS)—a computer program that allows the graphic development of project designs from standard modules. The DIS will search through records of previous designs to determine whether standard drawings, plans for existing buildings, or definitive designs are available with which to develop recommendations about space, planning, and arrangements for new construction or renovation projects. This system evaluates how closely a project design meets its goals and conforms to other project designs that have been used effectively by the Army. With this information and the development of standard modules for functional layout planning, the BSDS program can move standard modules around on a computer screen, and give degrees of common fit to produce effective designs from these modules.

### **3 STANDARDIZATION'S EFFECTS ON FACILITIES**

Standardization can have many effects on the usefulness of a facility. This chapter discusses the impacts of standardization on a facility's flexibility and functional life—its capacity to meet the needs of various occupants as long as it is used. To address "functional life" issues, architects and engineers must analyze during the initial design work not only life-cycle costs, but also mission-responsiveness for the future.

#### **Standardization and Facility Flexibility**

Building users and architects have tended to resist standardization and have overwhelmingly used the traditional "custom" designs for their projects. They believe that standardization is based on fixed laws of spatial organizations and construction that lead to standard solutions, visual boredom, and sterility limiting the facility's usefulness. This does not have to be the case. Architects have designed flexible, imaginative, and economical buildings using standard modules. This is the challenge that has been successfully met with industrialized building systems—architecturally the most successful standardized building to date.

In addition, the current widespread use of furniture systems for office designs has allowed many creative, flexible designs. Each office module or unit can be moved easily to meet the changing requirements of the user.

By combining in the same design methodology the best aspects of standardization and flexibility, the Corps can produce designs that not only meet users' needs, but also are economical.

#### **Standardization and Life-Cycle Costs**

High building costs, rising inflation, budget limitations, and Congressional hearings have created an increasing interest in getting the most out of the construction funds available. Experience has indicated that costs over the entire functional life of the building must be considered, and not just a portion of these costs—such as initial capital investment. With this more comprehensive concern, one must examine planning, design, and construction decisions with facility flexibility in mind. Thus, decisions about a facility's functional life are relevant from the beginning; construction costs are considered along with mission responsiveness, future use, energy consumption, and so on.

Industries, businesses, government agencies, institutions, and facility construction projects have been dealing with various aspects of life-cycle costing for years: research, design and development, production, and construction. Generally, however, these costs have been viewed separately, with very little attention to overall expenses—life-cycle costs, in other words.

The life-cycle cost is the total amount of money spent on an item, whether a product, project, or building. Life-cycle costs may include expenses for architects-engineers, development, construction material and labor, operation and maintenance, and disposal. Life-cycle costs may also be expressed as the total acquisition, operation, maintenance, and disposal costs. Thus, while life-cycle cost terminology may vary, the basic meaning of the term is the same.

Historically, the life-cycle cost for a facility construction project has been the total of three costs: (1) construction (or initial investment), (2) operation and maintenance, and (3) renovation.

The first cost of a building is considered the total initial investment required for building construction. First costs usually consist of architectural-engineering fees and construction contract amounts. Additional



first costs include the furnishings and equipment in buildings.

Operation and maintenance costs are recurring expenses that are necessary to operate and maintain a building during its functional life. Operating costs usually include supplies, labor, utilities, and minor repair work. A regular, annual schedule of minor or preventive maintenance may be followed, or maintenance may be performed only when necessary, such as when mechanical equipment needs to be replaced. In most cases, the maintenance policy would combine these approaches.

Sometime during the life cycle of a building, a major renovation may be needed to ensure that the facility meets the needs of the occupants. Building renovations begin a new cycle of investment, operation, and maintenance costs. Renovation may be thought of as a life cycle of its own (especially if a new mission has been assigned) or as a part of the total functional life of a building.

#### **Functional Life Analysis**

Identifying a facility's functional life helps ensure that the effects of a design decision will be identified early. Decision-makers often become preoccupied with initial costs and tend to neglect the overall costs that will result from their decisions. In addition, an awareness of functional life can make the analysis of facilities more effective. Project planners and designers usually have to make judgments about project sizes, the number of years various capabilities are assumed to be operational, and the like.

Functional life analysis and systems analysis are very similar. According to Gene H. Fisher, systems analyses may be defined as: "inquiry to assist decision-makers in choosing preferred courses of action by (1) systematically examining and reexamining the relevant objectives and alternative policies or strategies for achieving them; and (2) comparing quantitatively where possible the economic costs, effectiveness (benefits), and risks of alternatives."<sup>12</sup> Clearly, then, systems analysis can have many applications. A typical analysis is a sequence of steps, each building upon the information developed from the previous one, as shown in Table 1.

<sup>12</sup>Gene H. Fisher, *Cost Considerations in Systems Analysis* (American Elsevier Publishing Co., 1971).

The procedure outlined in Table 1 has been tested by CERL in a study for the Defense Logistics Agency (DLA)/Cameron Station in Alexandria, Va. The study involved assessing the office environment and examining a possible design alternative to the existing facility. Included with the architectural research was a functional-life-cost analysis comparing conventional General Services Administration (GSA) office furniture with that of furniture systems. This analysis proved to be most important in deciding which furniture to use. The following steps were taken:

1. Formulation: the "Issue" was the use of furniture systems providing better workstation flexibility than conventional furniture.

2. Search: data for both the conventional furniture and furniture systems were gathered. The data included costs, flexibility potential, and workstation square foot requirements. Thus, the scope of the Issue was determined.

3. Evaluation: the data obtained were analyzed and, based on this analysis, alternatives were compared. Thus, the rationale for considering the Issue was developed.

4. Interpretation: the analysis resulted in a program to set up, as a "test-bed," workstations made of furniture system components. Although components require a greater initial investment, they use less floor space than conventional furniture, thereby reducing floor area rental costs and future facility remodeling costs.

5. Verification: after construction and procurement, and when users have moved in, a workstation evaluation study will be done to verify the Issue determinations from Step 2.

The major challenge is to make personnel aware of the information needed to make decisions about a facility's functional life when planning and designing new buildings or retrofitting existing structures.

If functional life is considered, this information can be applied at the appropriate time in the building development process. The best source of facility data and relationships (for Fisher's Search phase) is mission-responsive programs information that includes comprehensive, integrated items—e.g., policy statements, user activities, facility requirements and criteria and design guidance. The best decisions about functional



**Table 1**  
**Steps in Analysis\***

Formulation (The conceptual phase)	Clarifying the objectives, defining the issues of primary concern, limiting the problem, searching out good criteria for choice.
Search (The research phase)	Looking for data and relationships, as well as alternative programs of action that have some chance of solving the problem.
Evaluation (The analytic phase)	Building various models, using them to predict the consequences that are likely to follow from each choice of alternatives, and then comparing the alternatives in terms of these consequences.
Interpretation (The judgmental phase)	Using the predictions obtained from the models and whatever other information or insight is relevant to compare the alternatives further, derive conclusions about them, and indicate a course of action.
Verification (The testing phase)	Testing the conclusions wherever possible.

\*From Gene H. Fisher, *Cost Considerations in Systems Analysis* (American Elsevier Publishing Co., 1971).

life are made if personnel are aware of all the implications policies and activities have for facility requirements and design solutions.

Developing information to describe the optimum functional life of permanent Army facilities presents many problems, which are solved in the private sector by appraising property for the greatest return on investment. The basis for a true economic comparison between new construction and rehabilitation is provided by the marketplace. Operation and maintenance costs can be passed on to the consumer. However, the functional life of the building must be considered in terms of the facility's effectiveness in meeting the needs of several users. There is, however, no equivalent financial basis for making decisions about the functional life of permanent military facilities. Return on investment usually is not determined by economics, but by the facility's effectiveness in satisfying mission requirements. Information about this effectiveness is related not only to the building itself, but also to other factors that change over time—for instance, weapons systems (e.g., new tanks), political climate, national concerns (e.g., energy conservation), or desired function changes (e.g., can an old library become a recreation center). Therefore, information for determining an

initial mission-responsive design and future functional life evaluations must be very comprehensive and easily updated. Providing such information is one of the goals of OCE's current standardization program. The development of standardized modules compatible with this program is discussed in Chapter 4.

## **4 PROCEDURE FOR DEVELOPING STANDARDIZED BUILDING MODULES**

The automated tools under development for the Corps of Engineers' DIS/BSDS will allow for rapid, extensive use of any designs that are produced, since they are to be based on standardized modules. Information about facilities' initial mission responsiveness and optimum functional life must be used to develop these modules.

Any system like the DIS/BSDS will produce facilities only as good as the information available for design. Thus, the system must have comprehensive information based on existing U.S. Army mission policies



and current military personnel activities—along with reasonable forecasts of the immediate future—so that mission-responsive, interactive, standardized modules are “in the computer” to be repeated over and over.

CERL Technical Report P-128 documents the development of a procedure to generate the comprehensive information that describes the relationship between users and a facility.<sup>13</sup> This procedure was tested by gathering mission-responsive information on TOE facilities for Organizational and Direct Support level maintenance operations. This information was also used to develop mission-responsive standard modules based on the following procedure.

From an analysis of the facility information, CERL generated six “concepts” that were then used to determine and develop standardized modules.\* The column heads in Table 2 list the six concepts, which are further developed in a standardized format described in Chapter 5.

Next, a three-stage format was developed to help in the identification, determination, and development of standardized modules. These stages (items A through C in Table 2 and Figures 1 through 3) correspond to the Formulation, Search, and Evaluation analyses presented in Table 1. Figure 1 shows the format for facilities where the operational activities are the most important factor in determining mission-responsive standardized modules. Figure 2 shows the format for facilities in which the building systems themselves are most important; in this analysis, the operational activities are considered in developing mission responsiveness in modules that have already been determined. Finally, Figure 3 shows the format for organizing various standardized modules into a total facility.

## 5 APPLYING THE STANDARDIZATION PROCEDURES

Decisions made either to evaluate an existing facility or to design a construction project require

<sup>13</sup>Robert Porter, Jon Rodgers, and Charles Lozar, *Developing Information for Mission-Responsive Maintenance Facilities*, Technical Report P-128 (CERL, September 1982).

\*In this context, “determine” refers to the initial decision about what the module needs to be, given its primary purpose. “Develop” refers to secondary decisions about a module’s relationship to other modules and the facility systems.

information that all participants agree to use as a “frame-of-reference.” The six concepts listed in Table 2 are such a frame-of-reference for TOE maintenance shop facilities.

Stages D and E of the analytical process in Table 2 were used to generate worksheets on mission-responsive standardized modules for TOE maintenance facilities (Figure 4). Similar worksheets are shown for three additional facilities: a controlled humidity warehouse for Prepositioned Material Configured to Unit Sets (POMCUS) installations (Figure 5), recreation facilities (Figure 6), and administrative offices (Figure 7). For TOE maintenance shops (Figure 4) and for recreation facilities (Figure 6), the operational activities were considered dominant in determining the modules, with the facility systems being satisfactorily accommodated through developing the modules. For the controlled humidity warehouses (Figure 5) and administrative offices (Figure 7), the building systems were considered dominant in determining the modules, with the operational activities being satisfactorily accommodated in developing the modules. Standardized modules for all facility types can be generated in either of these sequences. With the standardized module, “Interpretation” (usage in a design) and “Verification” (facility evaluation by using occupants) are identical for all projects (see Table 2).

The example standardized modules for TOE facilities were discussed with about 30 U.S. Army maintenance personnel at Forts Knox and Stewart. This review group verified that the primary mission capabilities for maintenance workstations are included in this analysis of facility information and should be made available for distribution as recommended planning and design guidance. The information now available for TOE maintenance shops, POMCUS installation warehouses, recreation centers, and administrative offices can be applied directly to the Corps of Engineers DIS/BSDS data bank. Information for other military facilities can also be generated and analyzed to develop similar mission-responsive standardized building modules.

## 6 CONCLUSION

This report has explained a logical approach to developing modular components for facility designs, and has documented a procedure for standardizing those modules while still maintaining a high level of mission responsiveness in the resulting constructed facilities.



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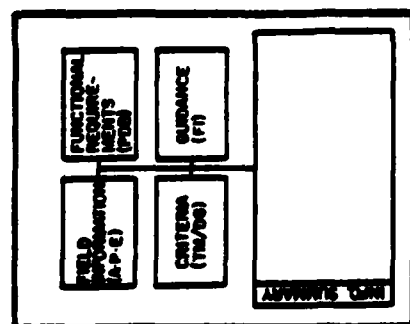
**Table 2**  
**The Six TOE Maintenance Facility Factors Used for Analyzing Standardized Modules**

<b>ANALYSIS SEQUENCE</b>		<b>1 Day Maintenance ACTIVITIES</b>	<b>2 Facility Mission CHALLENGES</b>	<b>3 Deployment Unit UTILIZATION</b>	<b>4 Organizational Unit INTEGRITY</b>	<b>5 COMMON Auxiliary Shops</b>	<b>6 COMMON Facility Services</b>
<b>A FORMULATION</b> from Information Summary	Clarifying the factors, defining the issues of primary concern, limiting the problem to the essence considerations.	Tracked vehicles "scheduled" service activities are those requiring the most space and the most equipment in the maintenance bay.	Different Army unit types are assigned to any particular facility. Each unit type has different shop requirements.	Maintenance facilities can be improved and "expanded" if the units shop and abrade yards are fully utilized.	The different company units can more easily maintain work effectiveness by having their combat and work areas adjacent to each other.	Each company requires specialty shop capabilities to augment their own bay area and equipment.	There are five functional areas that serve all of the distinct competencies, beyond maintenance needs.
<b>B SEARCH</b> for Module Determination	Looking for the data and relationships that are the determiners in solving the problem.	Power pack removal and maintenance determine the adequate space considerations for all maintenance bay modules.	A central core of flexible space that can be easily modified will enable each new tenant the choice of adjoining areas.	Both the shop control areas and the auxiliary shop areas can be augmented with vents--using a 12' module.	Supervision, instruction and production recording, along with personnel break and lounge areas need to relate directly to bays.	Group the common shops in a location that is easily accessible to all maintenance.	The facility support services can be grouped into modules that are located adjacent to the common shop modules.
<b>C EVALUATION</b> for Module Development	Building various additions at considerations into the module to accommodate them into a successful "total".	"Scheduled" service requires special exhaust time varying with space adjacent to the vehicle and with capacity within the bay module.	The central core requires easily adjusted components on a 4' grid--i.e., partitions, lighting, and heating units.	Each "bay" module requires an interior support area, panels, connections and a weather tight opening (whether in use or not).	Company support areas that are contiguous to their bays can support their integrity requirements by being "uninterruptible".	Efficient movement of personnel and equipment to the common shops requires direct and simple circulation corridors.	Distribution at utilities and access to common services should be equal for all the companies.
<b>D INTERPRETATION</b> as Module Usage in a BSDS Design	Use the predicted successful module to derive alternative facility designs--and construct them.	Corps of Engineers Dig/BSDS	Corps of Engineers Dig/BSDS	Corps of Engineers Dig/BSDS	Corps of Engineers Dig/BSDS	Corps of Engineers Dig/BSDS	Corps of Engineers Dig/BSDS
<b>E VERIFICATION</b> as Facility User Evaluation after Occupancy	Test the validity of the constructed environments to quantify facility responsiveness for users mission.	Installation Project Post-Occupancy Evaluation	Installation Project Post-Occupancy Evaluation	Installation Project Post-Occupancy Evaluation	Installation Project Post-Occupancy Evaluation	Installation Project Post-Occupancy Evaluation	Installation Project Post-Occupancy Evaluation



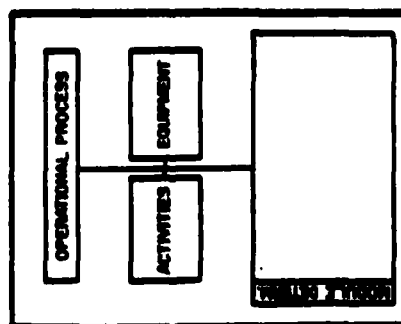
# MODULE DEVELOPMENT LOGIC

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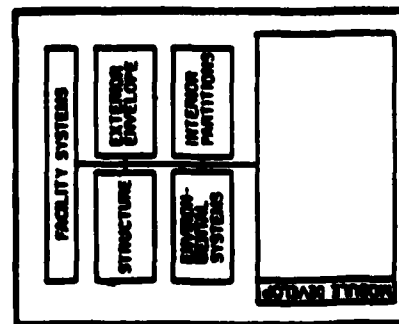
These are statements and diagrams that are extracted from the total information available. They define the specific ISSUES that present the "essence" considerations that the constructed facility must accommodate to be mission-responsive for the users.

INFORMATION SUMMARY



These are statements and diagrams that indicate how specific modules should be determined based upon an analysis of the operational processes that appear to dominate the potential for the facility to be mission responsive.

MODULE DETERMINATION



These are the statements and diagrams that indicate how the modules can be further developed to accommodate efficient and effective facility systems as the physical components of the building.

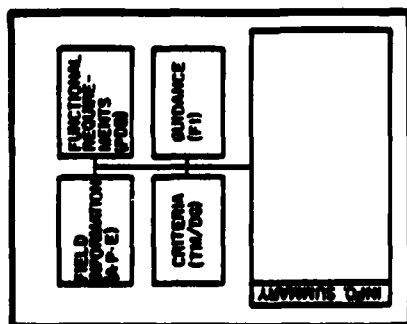
MODULE DEVELOPMENT

Figure 1. Operational activities as dominant factor.



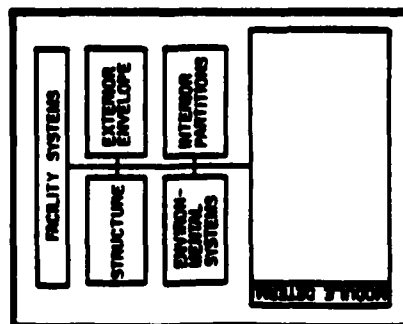
# MODULE DEVELOPMENT LOGIC

1b



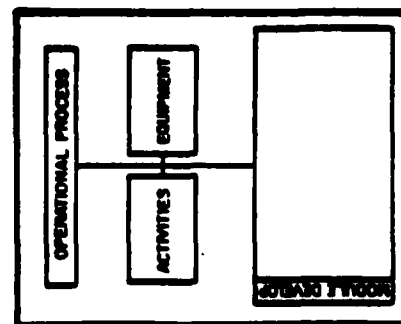
INFORMATION SUMMARY

These are statements and diagrams that are extracted from the total information available, that define the specific ISSUES that present the "essence" considerations that the constructed facility must accommodate to be mission-responsive for the users.



MODULE DETERMINATION

These are statements and diagrams that indicate how specific modules should be determined based upon an analysis of the facility systems and physical components of the building that appear to dominate the potential for the facility to be efficient and effective.



MODULE DEVELOPMENT

These are the statements and diagrams that indicate how the modules can be further developed to accommodate the necessary operational processes so that the facility can be optimally mission-responsive.

Figure 2. Building systems as dominant factor.



# MODULE DEVELOPMENT LOGIC

2

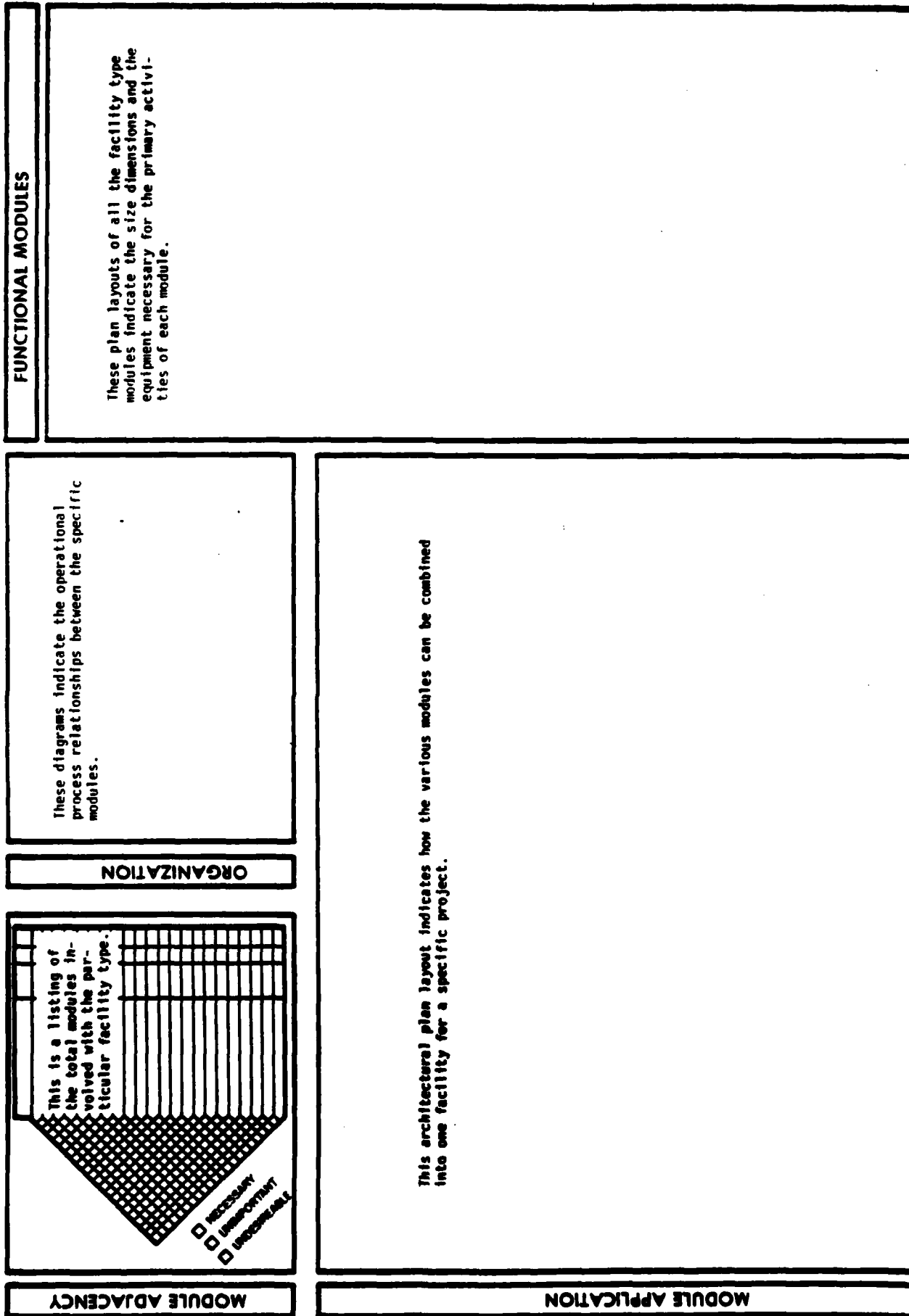
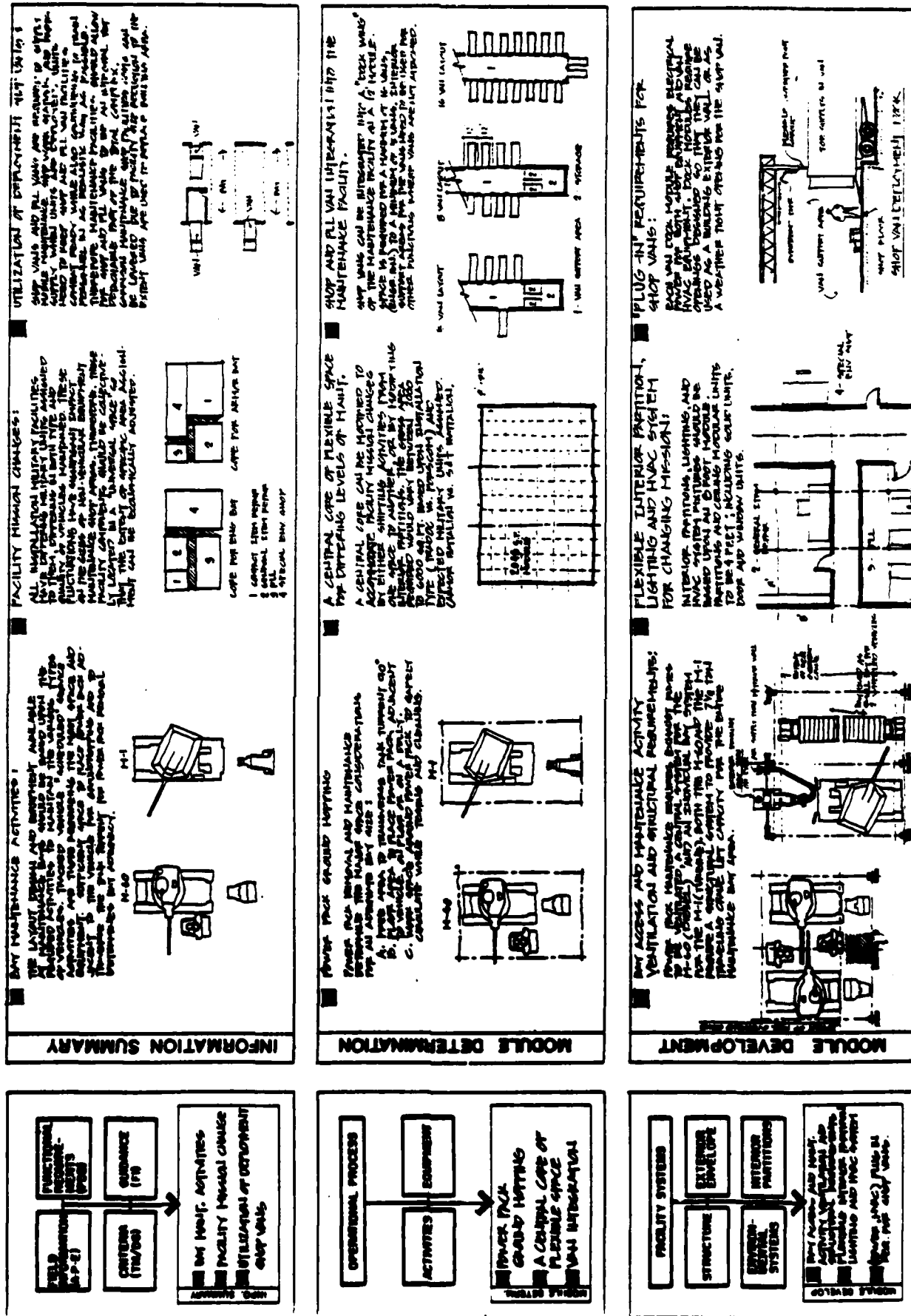


Figure 3. Organizing standardized modules into a total facility.



## MODULE DEVELOPMENT LOGIC



**Figure 4. TOE maintenance facilities.**



# MODULE DEVELOPMENT LOGIC TOE Maintenance Facilities

1a

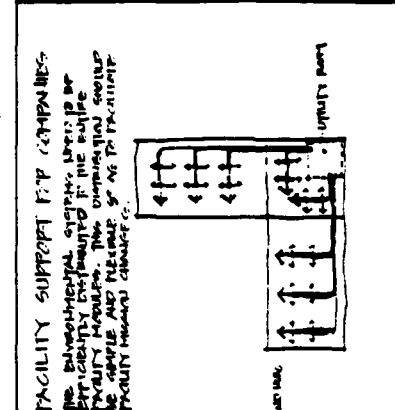
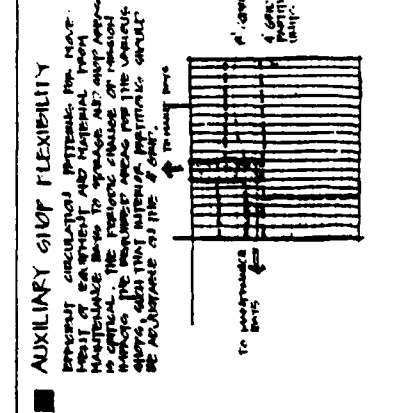
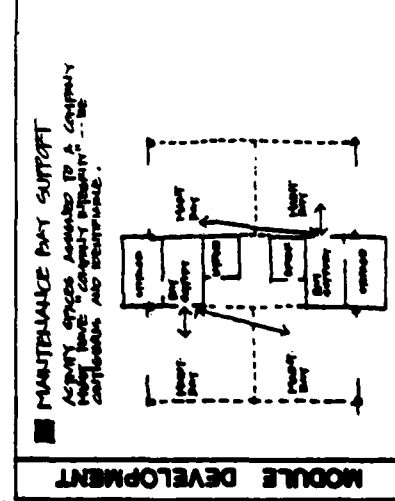
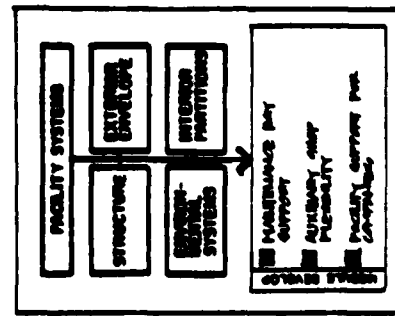
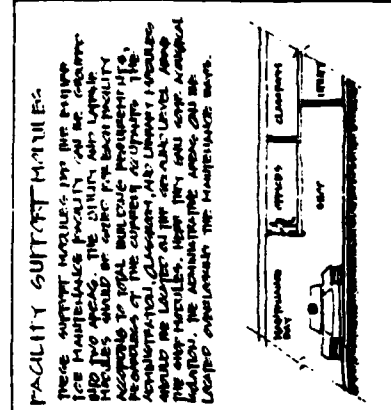
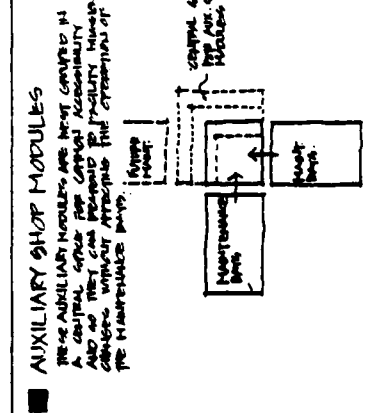
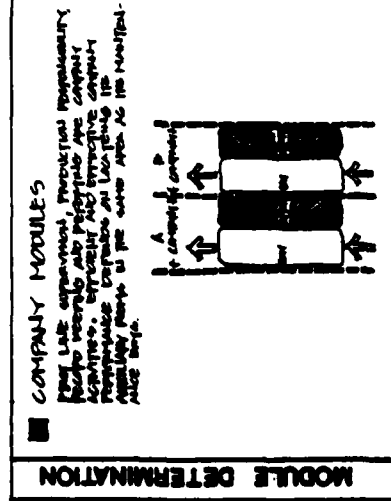
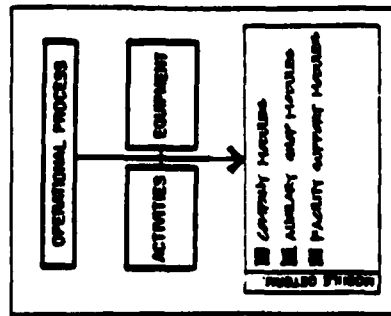
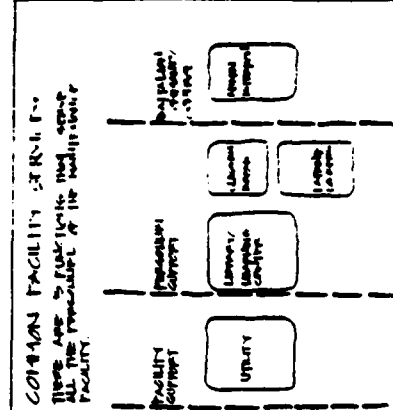
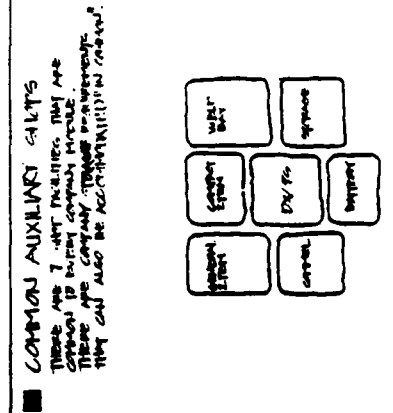
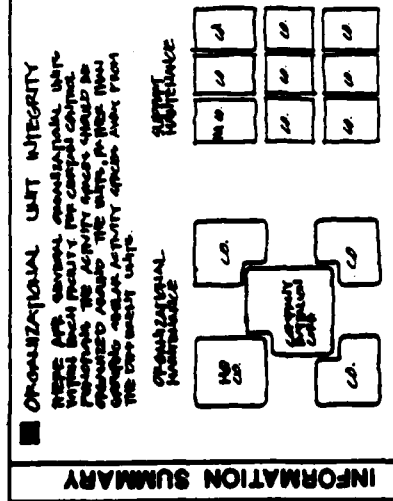
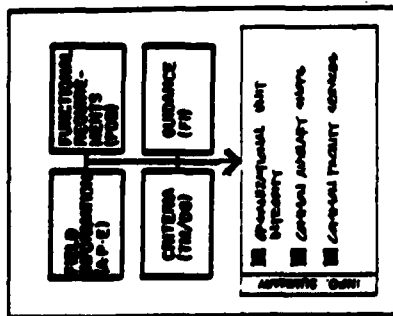


Figure 4. Cont'd.



## TOE Maintenance Facilities

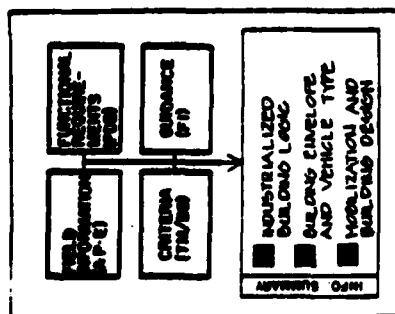
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**Figure 4. Cont'd.**



# MODULE DEVELOPMENT LOGIC POMCUS Storage Facility



**INDUSTRIALIZED BUILDING LOGIC**

THE NATURE OF THIS FACILITY (REPEITIVENESS OF UNIT TYPES, SCALE AND LAYOUT) CAN MAKE AN INDUSTRIALIZED BUILDING WHICH CAN BE BROUGHT TO THE SITE IN PIECES AND ERECTED QUICKLY. A STANDARD DESIGN CAN NOT ACHIEVE THE LAIDOUT REQUIRED.

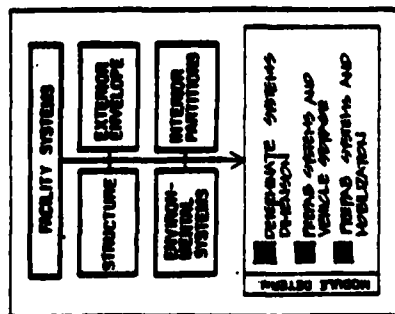
**BUILDING ENVELOPE AND VEHICLE TYPE**

IN EXCESSIVE LIGHT THE BUILDING ENVELOPE MUST CONFORM TO THE FOLLOWING CRITERIA:

- 1) SHIELD FROM THE ELEMENTS
- 2) HUMIDITY CONTROL
- 3) SECURITY CONTROL
- 4) MAXIMUM NUMBER OF VEHICLES (STRENGTH) UNDER MAXIMUM VOLUME

**MOBILIZATION AND BUILDING DESIGN**

INTO DEPLOYMENT OF VEHICLES REQUIRES STURDY MOBILE CONSTRUCTION. A LIGHT, PORTABLE, MODULAR, ALL-WEATHER, RAY-PROOF MODULAR WITH A MINIMUM NUMBER OF JOINTS.

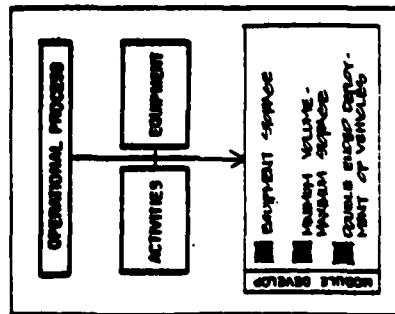


**DETERMINE SYSTEMS DIMENSION**

INDUSTRIALIZED BUILDING COMPONENTS CAN BE MADE TO BE PLACED AT 5'x10' DIMENSIONS WITH LAYOUT, SEVERAL SYSTEMS, INCLUDING RAY-PROOF, LIGHTING, SECURITY, FUEL, WATER, AND AIR, CAN BE PLACED IN THE BUILDING.

**PREFAB SYSTEMS AND VEHICLE STORAGE**

A PREFAB SYSTEM ALLOWS FOR A STORAGE FACILITY WHICH CAN ACCOMMODATE THE VARIOUS TYPES OF VEHICLES. THIS SYSTEM CREATES THE LARGEST VOLUME OF SPACE AVAILABLE IN THE MOST EFFICIENT MANNER. THE ENVELOPE CAN ALSO BE ADDED TO OF SUBSTITUTED FROM WITH RELATIVE EASE.



**EQUIPMENT STORAGE**

THE DESIGN BEHIND A 20'x40' MODULE IS THAT IT IS EFFICIENT FROM A SPATIAL STANDPOINT AND AT THE SAME TIME ACCOMMODATES THREE 14'x20' REAR-ENGINE TO SPACE THIS "BUS" MODULE ALSO ACCOMMODATES THE 5'x10' SPAN OF PREFAB BUILDING COMPONENTS.

**MINIMUM VOLUME - MAXIMUM STORAGE**

THE IDEA BEHIND THIS DESIGN IS TO PUT THE MAXIMUM AMOUNT OF EQUIPMENT IN THE SMALLEST VOLUME OF SPACE. THIS IS ACHIEVED BY USING A REAR-ENGINE TO SPACE THIS "BUS" MODULE ALSO ACCOMMODATES THE 5'x10' SPAN OF PREFAB BUILDING COMPONENTS. THE 14'x20' CHASSIS CAN BE USED IN MAXIMUM EFFICIENCY IN TERMS OF SPACE AND SPACE UTILIZATION. IT ALSO ALLOWS DIFFERENT UTILIZATION TO USE THE SAME DESIGN.

Figure 5. Controlled humidity warehouses.



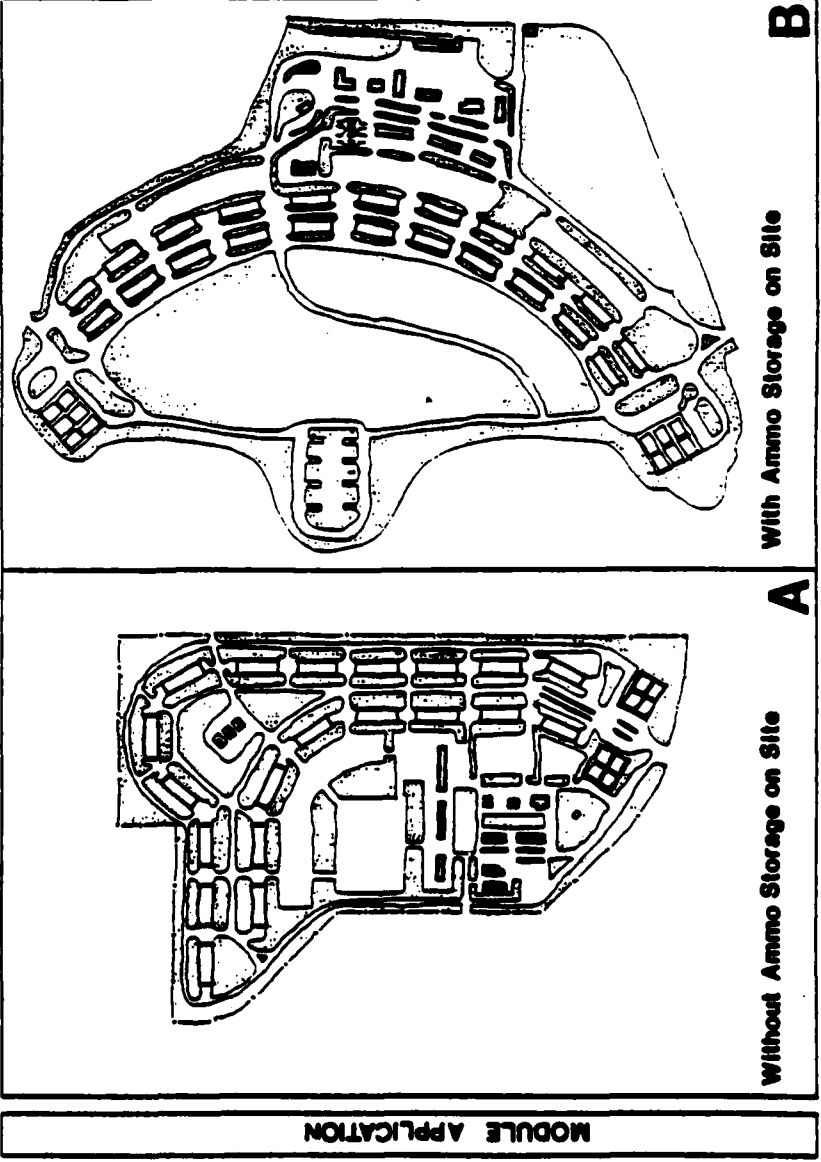
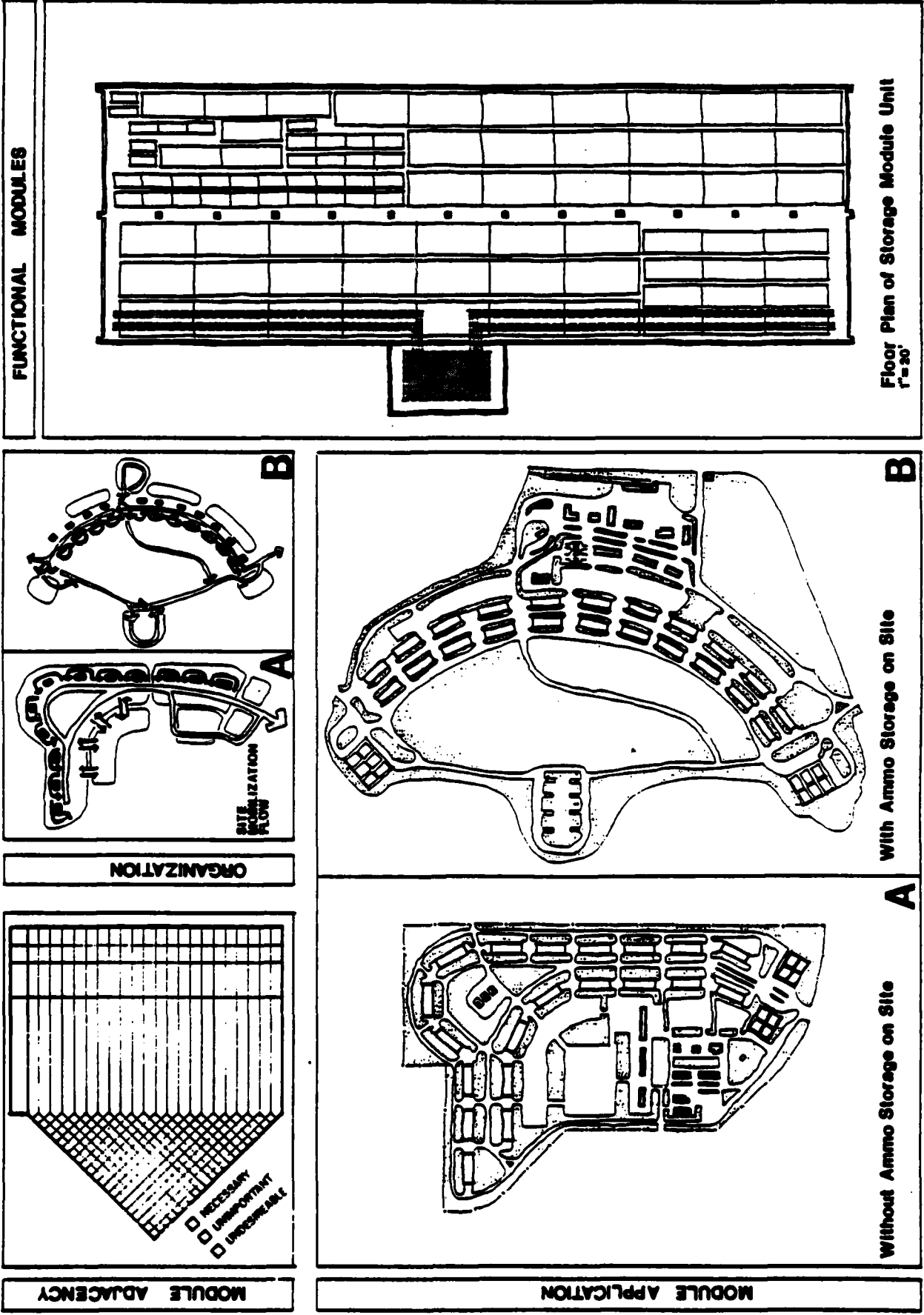


Figure 5. Cont'd.



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[illegible][illegible][illegible][illegible]

REC CENTER FLOOR PLAN

**Figure 6. Cont'd.**



# MODULE DEVELOPMENT LOGIC Office Building

1b

INFORMATION SUMMARY					
<p>INFO SUMMARY</p> <p>MODULE FUNCTION</p> <p>60A SPACE REQD</p>	<p>MODULE FUNCTION</p>	<p>CLERICAL ACTIVITIES:</p> <ul style="list-style-type: none"> <li>1) REPTAL STENO BE.</li> <li>2) REPTAL STENO BE.</li> <li>3) REPTAL STENO BE.</li> <li>4) REPTAL STENO BE.</li> <li>5) REPTAL STENO BE.</li> <li>6) REPTAL STENO BE.</li> <li>7) REPTAL STENO BE.</li> <li>8) REPTAL STENO BE.</li> <li>9) REPTAL STENO BE.</li> <li>10) REPTAL STENO BE.</li> </ul>	<p>SUPERVISORY ACTIVITIES:</p> <ul style="list-style-type: none"> <li>1) SUPERVISOR BE.</li> <li>2) SUPERVISOR BE.</li> <li>3) SUPERVISOR BE.</li> <li>4) SUPERVISOR BE.</li> <li>5) SUPERVISOR BE.</li> <li>6) SUPERVISOR BE.</li> <li>7) SUPERVISOR BE.</li> <li>8) SUPERVISOR BE.</li> <li>9) SUPERVISOR BE.</li> <li>10) SUPERVISOR BE.</li> </ul>	<p>TECHNICAL ACTIVITIES:</p> <ul style="list-style-type: none"> <li>1) TECHNICIAN BE.</li> <li>2) TECHNICIAN BE.</li> <li>3) TECHNICIAN BE.</li> <li>4) TECHNICIAN BE.</li> <li>5) TECHNICIAN BE.</li> <li>6) TECHNICIAN BE.</li> <li>7) TECHNICIAN BE.</li> <li>8) TECHNICIAN BE.</li> <li>9) TECHNICIAN BE.</li> <li>10) TECHNICIAN BE.</li> </ul>	<p>PROFESSIONAL ACTIVITIES:</p> <ul style="list-style-type: none"> <li>1) PROFESSIONAL BE.</li> <li>2) PROFESSIONAL BE.</li> <li>3) PROFESSIONAL BE.</li> <li>4) PROFESSIONAL BE.</li> <li>5) PROFESSIONAL BE.</li> <li>6) PROFESSIONAL BE.</li> <li>7) PROFESSIONAL BE.</li> <li>8) PROFESSIONAL BE.</li> <li>9) PROFESSIONAL BE.</li> <li>10) PROFESSIONAL BE.</li> </ul>

MODULE DETERMINATION	
<p>SYSTEMS LAYOUT</p>	<p>SYSTEMS LAYOUT</p>
<p>OPEN LAYOUT</p>	<p>OPEN LAYOUT</p>

MODULE DEVELOPMENT	
<p>SYSTEMS LAYOUT</p>	<p>SYSTEMS LAYOUT</p>
<p>OPEN LAYOUT</p>	<p>OPEN LAYOUT</p>

Figure 7. Administrative offices.



MODULE DEVELOPMENT LOGIC Office Building

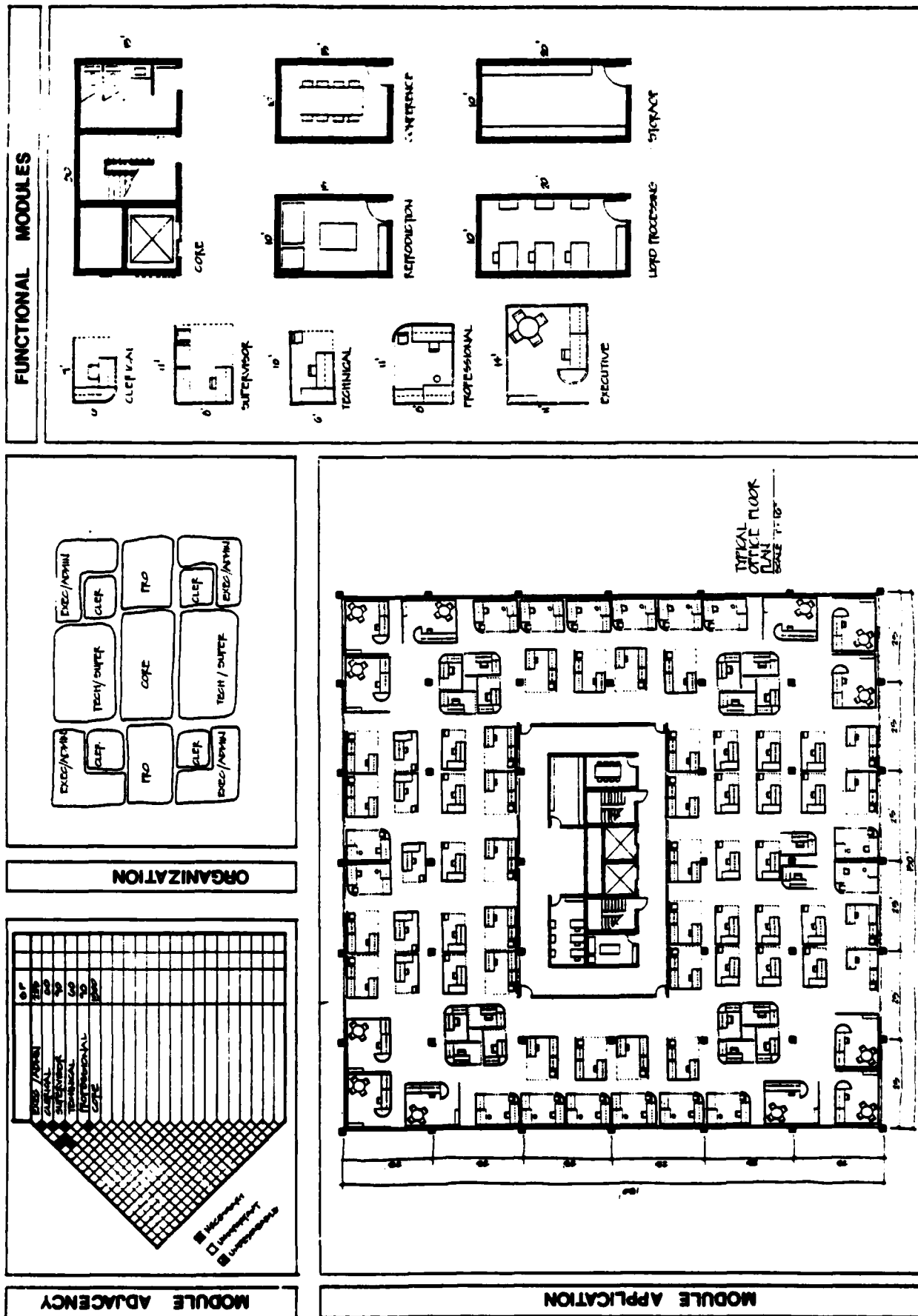


Figure 7. Cont'd.



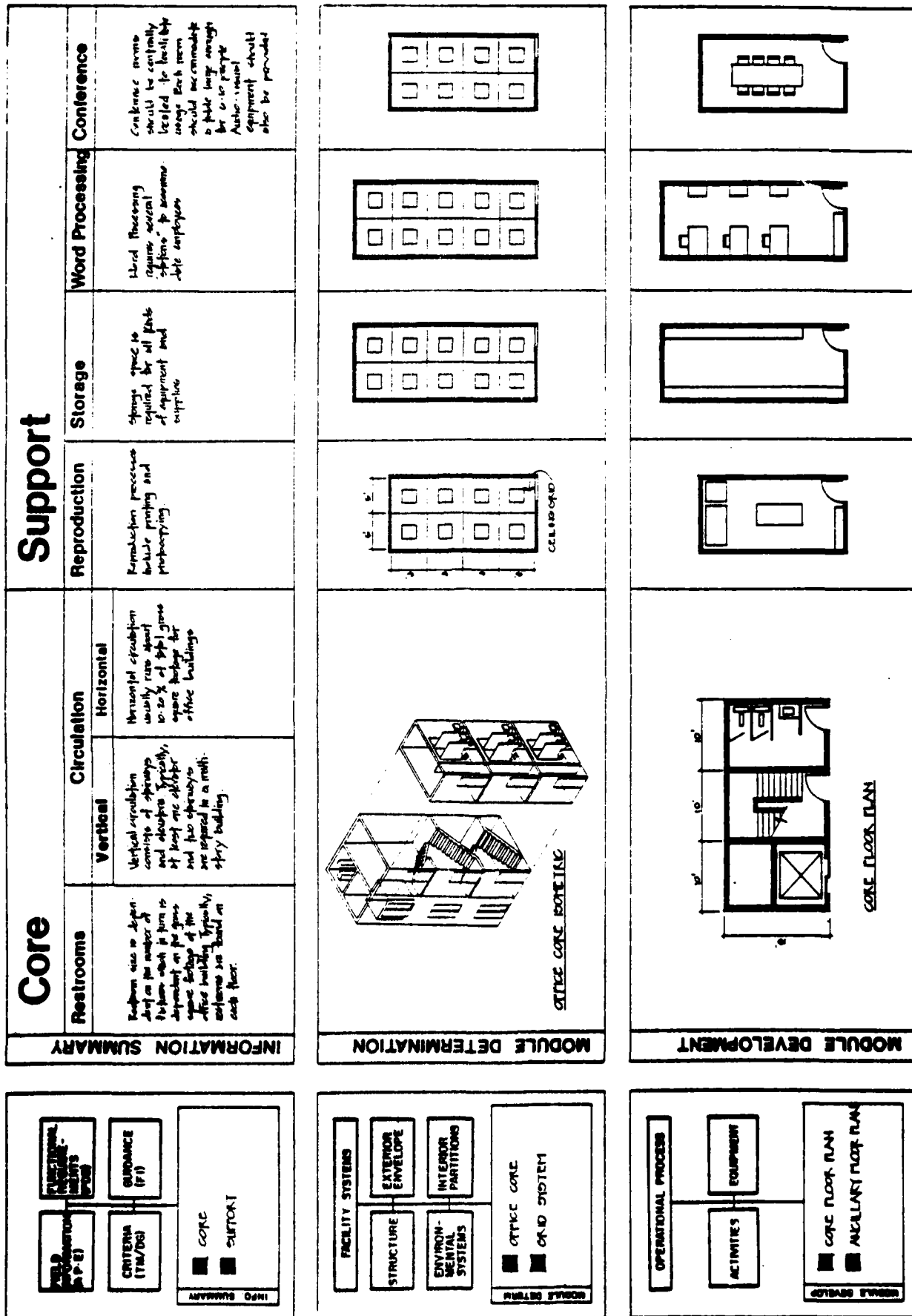


Figure 7. (Cont'd).



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